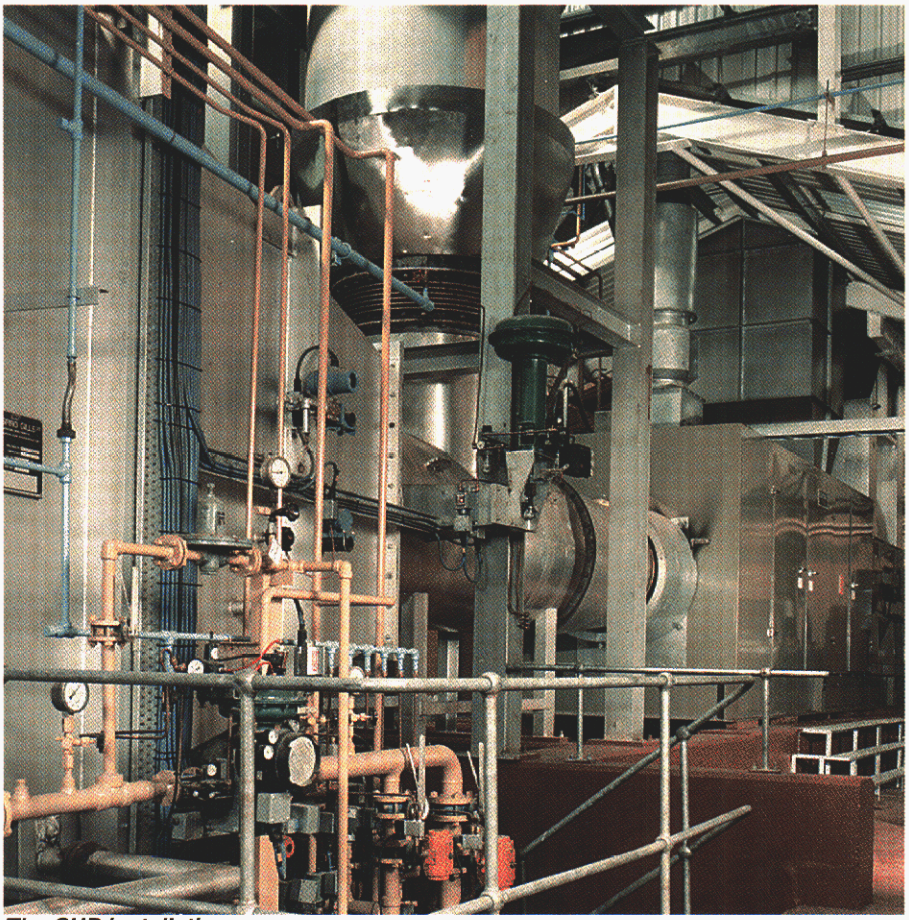
Case Study 209

The long-term performance of a CHP installation using an aero-derived gas turbine



The CHP installation

Case Study Summary

The CHP scheme installed at the paper mill operated by Smith, Stone & Knight Ltd (SSK) has now been functioning for over seven years. During the first four years, prior to a major expansion of the mill's production capacity, the installation provided almost all of the mill's requirements for electricity and steam, reducing energy costs by more than 30%.

The project involved the installation of a 3.63 MWe gas-turbine driven generating set and a water-tube heat-recovery boiler. A supplementary gas burner arrangement in the boiler inlet gas duct provides the additional heat necessary to increase steam production to a maximum of 22.7 tonnes/hour. System availability has been high (greater than 98%), and overall thermal efficiency has averaged 74.0% (gross calorific value). The overall heat:power ratio is 3.28:1.

Host Organisation

Smith, Stone & Knight Ltd
Trevor Street
Nechells
Birmingham
B7 5RE

Monitoring Organisation

Thermal Developments Ltd
The Whins
North End
Sedgefield
Stockton-on-Tees
Cleveland
TS21 2AZ
Tel No: 0740 621614
Dr R Nicholson

Case Study Objectives

To evaluate the long-term performance and reliability of a combined heat and power (CHP) scheme and to reassess the economics of the project, taking account of current energy prices and installation costs.

Potential Users

Continuous process industries including paper and board, chemicals, food & drink, oil refining, petrochemicals and pharmaceuticals.

Investment Cost

£1.628 million (1984/5 prices).

£2.850 million (1993 prices).

Savings Achieved

Cost saving: £819,000/year (1993 energy prices).

Primary energy saving: 155 TJ/year.

Payback Period

Actual payback: approximately 3 years.

Payback at 1993 prices: 3.5 years.

Equipment Manufacturers

Gas Turbine:
Centrax Ltd
Gas Turbine Division
Shaldon Road
Newton Abbot
Devon
TQ12 4SQ
Tel No: 0626 52251
Mr R A Stallard

Waste Heat Boiler:
GEA Iberica
(agents for Deltak Corporation)
c/o GEA Spiro-Gills
London Road
Pulborough
West Sussex
RH20 1AR
Tel No: 0798 872401
Mr M J Peyser

BEST PRACTICE PROGRAMME

Energy Efficiency Office
DEPARTMENT OF THE ENVIRONMENT

"... net cost savings currently worth more than £800,000/year"

Project Rationale

SSK's Birmingham mill operates continuously for 8,400 hours/year, converting waste paper into packaging materials. In 1984, prior to the installation of the CHP scheme, there was no on-site electricity generation, and steam was provided by four ageing, oil-fired, shell boilers. The energy requirements for a mill output of 48,000 tonnes/year were 13 tonnes/hour of steam, and an electricity demand averaging 2.6 MWe.

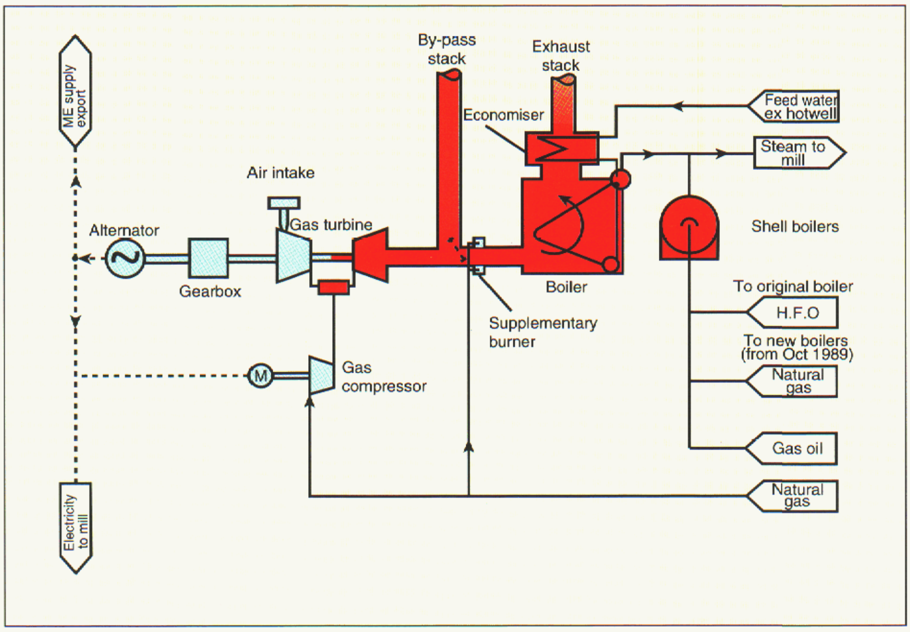
Following the introduction of the Energy Act (1983), which permitted private generators to export electricity, SSK perceived that on-site electricity generation could be an economic proposition. A feasibility study examined various CHP options before recommending the installation of a gas turbine with a supplementary fired heat-recovery boiler. This system closely matched the mill's heat and power requirements.

Because of its innovative features and energy-saving potential, the project received support from the Energy Efficiency Office (EEO) under the Energy Efficiency Demonstration Scheme, now replaced by the Best Practice programme. The CHP system was independently monitored throughout its first year of operation and, in January 1993, was reassessed to determine its long-term reliability and cost-effectiveness.

The CHP System

The prime mover for the system is an aero-derived gas turbine rated at 3.63 MWe. The turbine is fuelled by natural gas supplied on an interruptible tariff. Electrical power is produced at 11 kV and fed to the mill's distribution system.

The gas turbine exhaust discharges to a two-drum, natural-circulation, water-tube, heat-recovery boiler and economiser, where it is capable of generating steam at the rate of 10.4 tonnes/hour.



Gas turbine CHP system

The ducting between the turbine and the boiler incorporates a pneumatically-operated damper system: this allows the gas turbine exhaust to pass either to the boiler or to a bypass stack discharging to atmosphere. Supplementary gas burners in the boiler inlet duct provide the additional heat necessary to raise steam production to a maximum of 22.7 tonnes/hour.

Steam from the boiler drum is piped to the mill distribution manifold in the existing boiler house.

The CHP electrical system normally operates in parallel with the Midlands Electricity plc (ME) supply and, when electrical generation exceeds the mill load, it is usually economic to export surplus power to the grid. However, if surplus power becomes available during the night when ME purchase tariffs are lowest, a control loop ensures that gas turbine output is modulated to reduce the exhaust flow rate.

When the gas supply is interrupted (or the generator is not available) the entire system is shut down. All power is then purchased from ME and the mill's steam requirements are provided by alternative boilers.

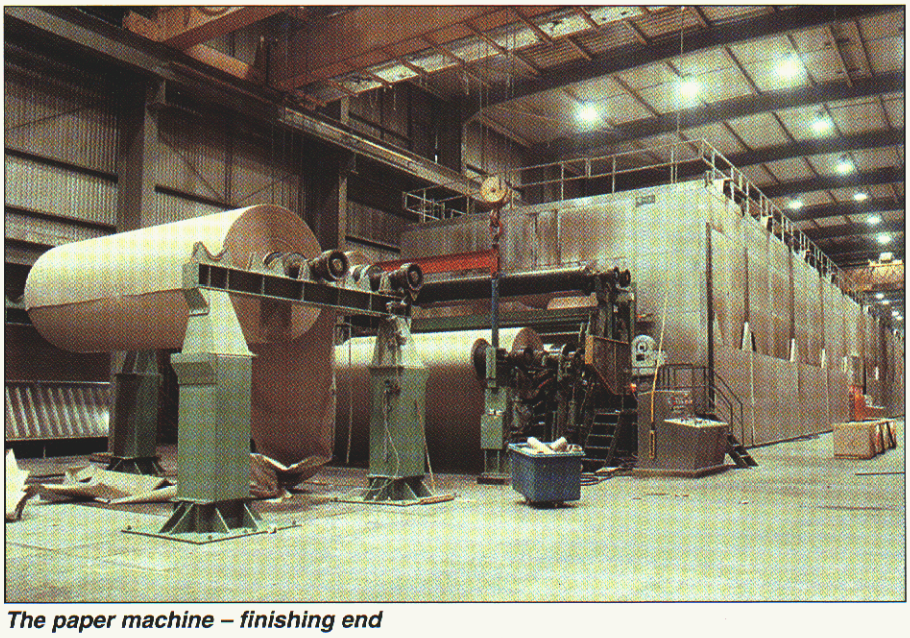
Operational Experience

The CHP system was installed and commissioned in 1985 with minimal disruption to production. After only a few weeks of operation, failure of the power take-off shaft bearing on the gas turbine caused damage to the power take-off shaft, gearbox and generator drive-end bearing. Emergency repairs ensured that the set was returned to full load within 18 days, and no production losses were incurred.

In 1986, after some 9,000 running hours, the turbine required extensive refurbishment and modification to overcome a blade overheating problem. This work was carried out with minimal disruption and largely at the manufacturer's expense. An on-line washing system has also been installed to clean the compressor blades.

Since 1986 the gas turbine has suffered no significant unscheduled downtime, and virtually all maintenance work has been completed during mill shutdowns. By the end of 1992 it had operated for almost 61,000 hours, averaging 8,000 running hours/year, with an availability of more than 98%. Gas supply interruptions have been infrequent and of short duration, so the lack of a secondary fuel supply has not been a handicap. The gas compressor has proved to be very reliable, with servicing carried out annually by the manufacturer.

During the commissioning of a new paper machine in October 1989, the existing condensate system became contaminated with



The paper machine – finishing end

mill scale from new steam and condensate piping. This contamination was carried through to the heat-recovery boiler, blocking 14 of its water tubes and causing them to burst. A complete inspection and extensive repairs were therefore necessary.

Apart from the start-up and compressor-washing procedures the system is fully automatic, requiring only a visual inspection and the logging of operating data twice daily. One of the successes of this project has been the operation of the CHP plant by previously inexperienced mill staff.

Energy Use

Between 1985 and 1989 the CHP system provided virtually all of the mill's steam and electricity requirements, generating approximately 27 GWh/year (3.4 MW) of electricity and 15 tonnes/hour of steam. Output during this period increased from 48,000 to 55,000 tonnes/year. In 1989, the three existing and relatively small paper machines were replaced by a much larger machine capable of producing 150,000 tonnes/year. This significant increase in mill capacity has more than doubled both electricity and steam consumption. Purchased electricity has increased from almost nothing to 37 GWh/year, while the balance of the steam demand is met by three new 21 tonne/hour dual-fuel package boilers. The original shell boilers have now been removed.

The overall thermal efficiency of the CHP system has averaged 74.0% (gross calorific value). The conversion of fuel to electricity is 17.3%, giving a heat to power ratio of 3.28:1.

The CHP system has reduced national primary energy consumption by 155 TJ/year (5,900 tonnes coal equivalent). Site energy consumption is shown in the accompanying table.

Mean annual energy use and energy cost savings: 1985-1992 (1993 prices)

	Energy usage '000 units	Unit cost p/unit	Cost/(Credit) £'000
CHP system			
CHP fuel			
Natural gas (therms)	5,164	18.0	929.5
Boiler fuel[a]			
HFO (therms)	86	18.8[b]	16.2
Power			
Purchased (kWh)	15,439	4.3[c]	663.9
Exported (kWh)	942	3.1	(29.2)
Total energy costs			**1,580.4**
Purchased power/packaged boilers			
Boiler fuel[a]			
HFO (therms)	3,748	18.8	705.7
Power			
Purchased (kWh)	40,667	4.3[c]	1,748.7
Total energy costs			**2,454.4**
CHP operating cost advantage			**874.0**

Notes:

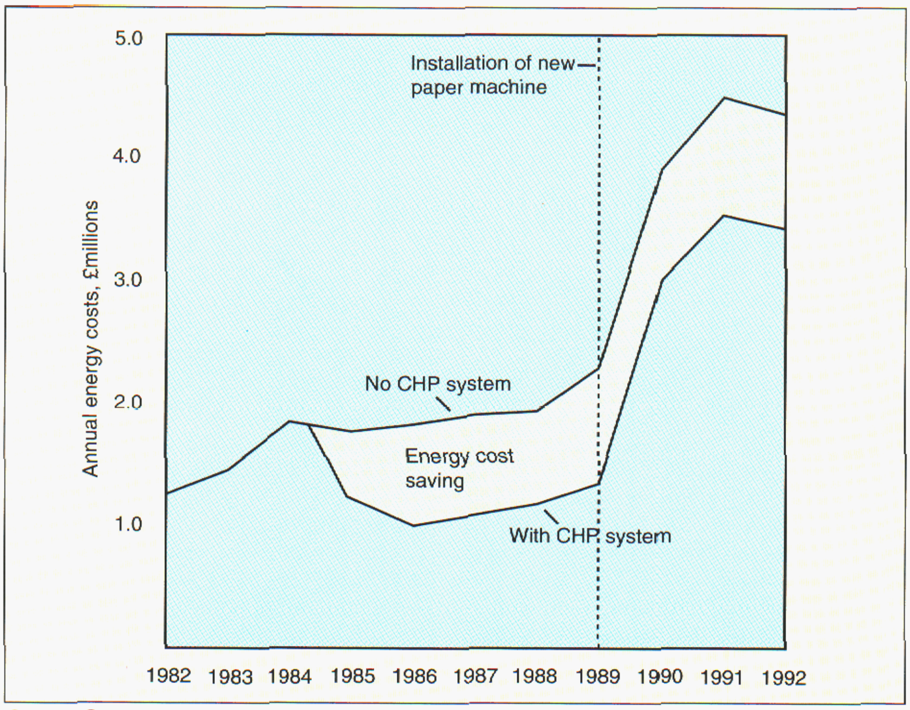
a Excludes fuel to new boilers operating alongside CHP system.

b For natural gas and HFO priced equally on the basis of net calorific value, the energy costs are the same (HFO at 18.8p/therm gross is equivalent to natural gas at 18.0p/therm gross).

c All-year weighted mean costs.

Environmental Benefit

The project has reduced the emission of carbon dioxide by some 28,000 tonnes/year, or 50% at the original mill output. This assumes that the CHP plant's electricity generation displaces that provided by a coal-fired power station.



Smith, Stone & Knight annual energy costs and savings

Cost Savings and Payback

The mean annual energy costs for 1985-1992, excluding those incurred by the additional boiler plant, are shown in the accompanying table for both the CHP system and pre-CHP operation. They are based on typical 1993 prices.

The capital cost of the project in 1984/85 was £1.628 million and, despite considerable variations in fuel prices in the early years of operation, the simple payback period achieved at SSK was approximately 3 years.

The CHP system reduces energy costs by £874,000/year. Against this must be set the associated maintenance costs. These have averaged £70,000/year (1993 prices), excluding the one-off cost of some £200,000 associated with boiler repairs in 1989. Allowing £15,000/year for avoided maintenance on the almost unused shell boilers, the net additional maintenance cost is £55,000/year.

Net cost savings are therefore £819,000/year.

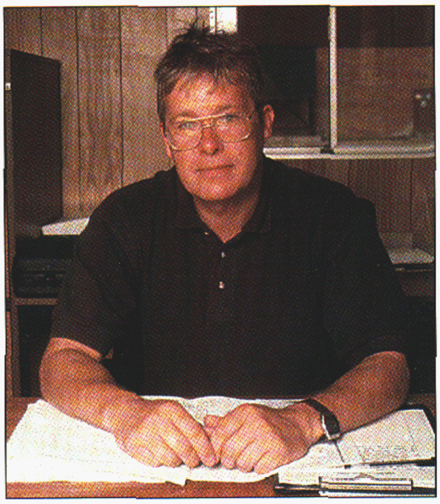
For a similar installation in 1993 the capital cost would be approximately £2.850 million giving a payback period of 3.5 years, assuming that current energy prices remain unchanged.

Comments from Smith, Stone & Knight

Smith, Stone & Knight is very conscious of the effect of energy costs on mill profitability and, in the late 1970s, gave priority to reducing these costs by installing a Monitoring and Targeting system. This proved most effective, within the limits of the system, but did not achieve the main objective of reducing total energy usage to 100 therms of primary energy per tonne of paper sold.

In 1984/85, after a feasibility study, the company decided to invest in the first aero-derived turbine used for CHP in the UK. A turbine failure shortly after initial start-up was quickly repaired and, apart from boiler problems during the installation of a new paper machine in 1989, the plant as a whole has operated most satisfactorily with a very high level of availability. With the exception of start-up the plant is fully automatic, requiring only a visual inspection once or twice every 24 hours.

This has proved to be a very worthwhile and cost-effective project, with net cost savings currently worth more than £800,000/year. Mill output, however, has increased three-fold since the initial installation, and the CHP plant no longer meets total mill requirements for steam and electricity. The company is therefore considering a second installation to meet these enhanced requirements.



Alan Clarke.

Smith, Stone & Knight Ltd

Smith, Stone & Knight Ltd

Smith, Stone & Knight Ltd is a wholly owned subsidiary of the Roermond Group. The company's paper mill at Nechells, Birmingham produces 150,000 tonnes/year of packaging materials from waste paper. The company places considerable emphasis on improving both the quality of its products and its levels of energy efficiency.

Mr Alan Clarke
Works Electrical Engineer
Smith, Stone & Knight Ltd

The project described here was selected as an example of Good Practice, which is one element of the Energy Efficiency Office's (EEO) Best Practice programme, an initiative aimed at advancing and promoting ways of improving the efficiency with which energy is used in the UK.

This case study replaces the original Expanded Project Profile No 188. More details of the long-term performance of this and two other gas-turbine-based CHP projects are available as General Information Report 20. For further copies of this Case Study or other Best Practice programme publications, please contact the Energy Efficiency Enquiries Bureau, ETSU, Harwell, Oxfordshire. OX11 0RA. Tel No: 0235 436747. Telex No: 83135. Fax No: 0235 432923.

For buildings-related projects, please contact: Enquiries Bureau, Building Research Energy Conservation Unit (BRECSU), Building Research Establishment, Garston, Watford WD2 7JR. Tel No: 0923 664258. Fax No: 0923 664787.

Information on participation in the Best Practice programme and on energy efficiency generally is also available from your Regional Energy Efficiency Office.